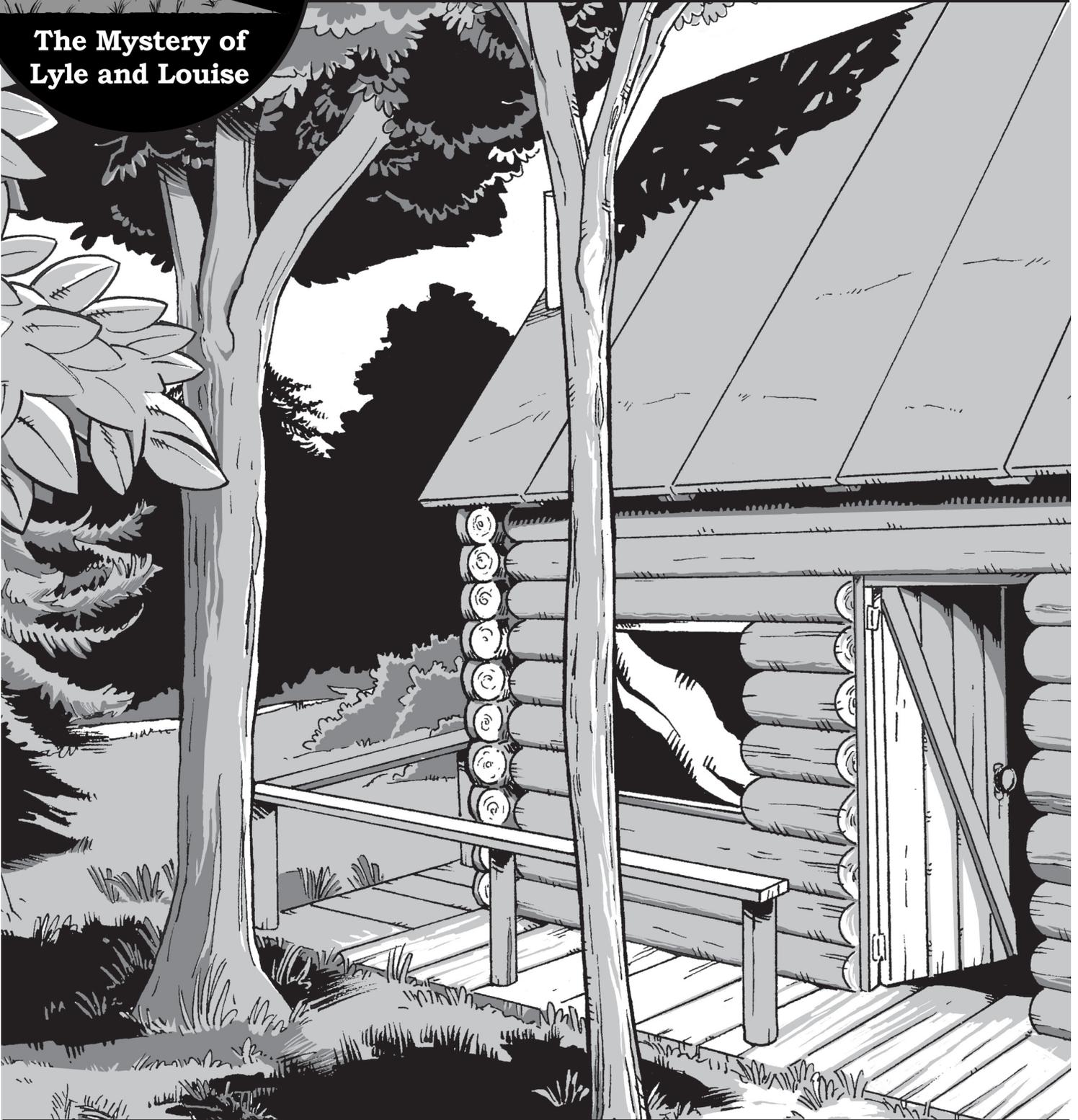


**The Mystery of  
Lyle and Louise**

# The Shoe Must Fit

**A Lab on Footprints Analysis**



**F**OOTPRINTS are found at approximately 40% of crime scenes. Second only to DNA as the most common evidence type found, footprints are an excellent source of information because each print is unique to the wearer. Footwear marks are particularly useful in crimes where proof of presence is incriminating. The terms shoe prints, foot prints, or footwear marks are interchangeable and refer to two types of impressions left by a person's footwear: positive and negative. A positive, or two-dimensional, impression is created by a person transferring matter, such as dust or blood, from their shoe to the surface they walk on. A negative, or three-dimensional, impression is created when the shoe removes residue from the surface it walks on, as would happen when a person walked through mud or cement.

As long as people have been walking, there have been footprints. The world's oldest footprint, estimated to be over 3 million years old, was discovered in 2007 at Siwa Oasis in Egypt. The first recorded forensic use of footprints occurred in the early 1800s in Warwick, England. In 1816, a young maidservant was discovered drowned in a shallow pool of water, and evidence discovered upon her body indicated that she had been violently assaulted. While investigating the damp ground around the pool of water, police discovered footprints and an impression of corduroy cloth with a patch sewn upon it. Bits of grain were found surrounding the prints and lead police to a nearby farm. Police examined the pants and shoes of a farm laborer who was threshing wheat and discovered a match to the impressions found at the crime scene.

In the more recent trial resulting from the 1994 murders of Nicole Brown Simpson and Ronald Goldman, part of the inculpatory, or incriminating, evidence came from a bloody footprint found at the crime scene. William Bodziak, an FBI footprint expert, confirmed that the prints came from size 12 Bruno Magli Shoes. Incidentally, these particular shoes are extremely rare and only 299 pairs were sold in the US. When the evidence was presented the prosecution had no proof that the defendant,

Orenthal James "O.J." Simpson, had ever purchased such shoes. Later on in the trial, however, a tabloid photograph surfaced with O.J. Simpson wearing the shoes in question. With other supporting evidence, O.J. Simpson was arraigned for the two murders.

Unabomber Theodore Kaczynski is currently serving a life sentence with no chance of parole as a result of his bombing spree that lasted from 1978 to 1995. While collecting evidence from his secluded Montana cabin, investigators discovered shoes with fake soles. By attaching soles from a smaller-sized shoe to his own shoe, Kaczynski had hoped to mislead police. Kaczynski pled guilty to his crimes.

When examining a footprint, investigators look for several identifying features. Class characteristics are unique to all shoes of that brand and style, such as outsole patterns, symbols, and design features. Class characteristics aid the investigators in determining the manufacturer of the shoe. The type or brand of the shoe is always determined so the exact size of shoe can then be appraised. In many cases, the impression may be such that experts can identify the specific brand and style of shoe that the criminal used, even to the possible exclusion of other brands or sizes.

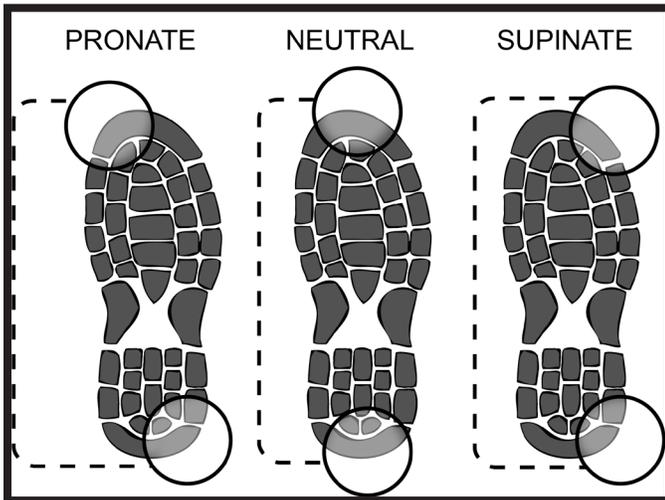
Each shoe has individual characteristics which are unique to that shoe. Individual characteristics of a shoe would include manufacturing irregularities, chips or holes in the tread, and any substance added to or removed from the shoe during wear. Several items that could be picked up while the individual is walking include rocks, gum, tar, tacks, or nails. During normal wear, shoe rubber can crack or warp, and pieces of rubber may be removed. Rocks or other sharp objects may create a hole or indentation. Those individual characteristics can help narrow down the search for a specific shoe.

A wear pattern is formed by the gradual wearing away of rubber by the friction created between the walking surface and the sole of the shoe. The longer the shoe is worn, the more pronounced the wear pattern becomes. Wear would be more pronounced where the foot first makes contact with the ground.

# Footprint Analysis

By looking at the wear pattern, investigators are able to assess the walking pattern of the individual. A wear pattern on the outside rear of the shoe near the heel would indicate that the walker underpronates or walks with supination (with the ankle turned out, away from the other foot). Wear on the inside of the shoe towards the toe would come from

an individual who overpronates (or walks with the ankle turned in, towards the other foot). A print that is uniform across the forefront would result from a wearer that walks with neutral or normal pronation (with the foot coming into contact with the ground evenly).



When analyzing a footprint there is no minimum number of class or individual characteristics needed to establish identification: one characteristic alone could be used to identify a shoe, as long as the characteristic was clear, detailed, defined, and contained significant features in common with the impression. It would be highly remarkable to find the same mark in the same position on two different shoes making positive identification with a suspect's shoe possible, however, if the similar characteristic was merely a simple hole or pinprick that could be easily found on multiple shoes and more identifying characteristics would be sought.

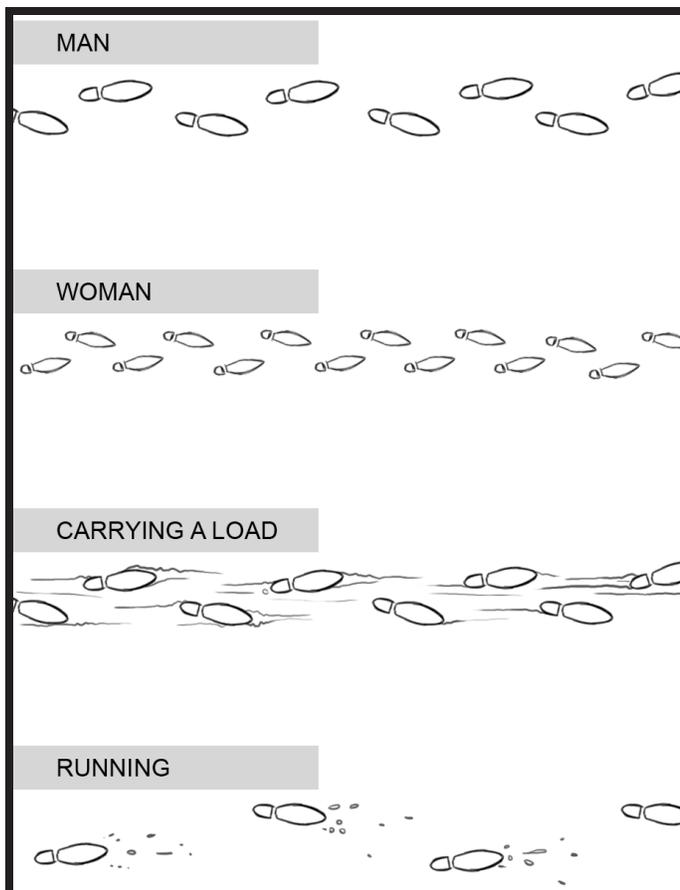
In 2007, the United Kingdom Forensic Science Service launched the world's first national database of shoe imprints. This database holds detailed information about shoe prints found at all crime scenes across the country. In addition, the shoes of thousands of suspects are added to the database each year. As new shoe patterns are added to the database, they will be matched against prints in the database. Foster + Freeman Ltd., based out of Worcestershire, England, has developed a program system called SICAR which is frequently used by police departments in Europe, the United Kingdom, and the United States. The SICAR system has a coding technique that can create a coded description from the shoe mark's patterns in as little as two minutes. The code is then used to determine the frequency of that shoe print at the crime scene and is compared against other prints in the system to find a possible match. The system also has an image compositor that will aid in identifying partial prints. Several partial prints can be scanned into the system which joins them together to present a more complete image.

The United States does not currently have a national database exclusively for footprints, however, research funded by the U.S. Department of Justice is currently being completed by computer scientists at the University at Buffalo and State University of New York. The State University of New York is working on developing algorithms for matching shoe prints. They are hoping to automate the process to make it a query search similar to that of Google search. Research is not yet completed. There are also two commercial databases, Treadmark and Solemate, that help identify the types of shoes found at a crime scene. Treadmark uses four parameters to help identify outside sole impressions to ease the time-consuming recovery. Solemate is a database holding manufacturer information and several pictorial images to help determine the type of shoe the print belongs to. This database has over 12,000 different shoes including work, sports, and casual shoes.

# Footprint Analysis

Additional information may be appraised from footprints that may indicate direction and rate of movement, sex, and whether the individual knows he or she is being tracked. Smaller footprints that are slightly pigeon-toed with a small stride would indicate that the prints likely belong to a woman, as men tend to walk with their toes pointed straight forward or tilted slightly outward. Deep prints, with the front of the foot pressed deeper into the ground than the rest of the print, and a long stride would indicate a faster pace of walking or running. The depth of a footprint can also be useful in giving a rather accurate weight for the person if the weight was evenly distributed along the print. Prints that appear consistently deeper on one foot indicates that the person was carrying something on that side.

A person's gait, such as their stride length and width, can also be determined by footprints. Investigators will study the stride length, or the distance between two heel prints of the same foot. When



stride length is used in correlation with shoe size, investigators can make an estimation of height. Foot length is approximately 15% of the person's height. Though this ratio does not apply to 10-20% of the population, it does help to narrow down the suspects and give a very good idea of the individual sought.

Recovering footprints is a somewhat tedious process, as all surfaces must be considered to hold prints. William Bodziak has argued that investigators do not always take the necessary care to collect possible footprints. Bodziak is often quoted for saying, "What is not looked for will not be found!" It is frequently assumed that there will be fingerprints at a crime scene, but, unfortunately, footprints are sometimes neglected. Forensic technicians are trained to remember that every step taken by the criminal will leave a mark or impression of some type, therefore, before entering the crime scene, an expert will think about what happened at the scene, if footprints are relevant to the case, and identify specific areas where footprints may be found. Items such as floors, paper, glass, cardboard, and all other surfaces that may have been walked on should be considered for possible footprints. By shining a strong, oblique light onto the floor of a darkened room, footprints that were previously hidden may be visualized. Care must be taken by the crime teams not to disturb the evidence left by the criminal. If enough time and effort is administered, most surfaces will surrender a print.

When considering the vast variety of surfaces that yield prints, it has become necessary to develop multiple techniques to lift the prints with the least amount of distortion. Before the print is lifted, photography is an essential step of any crime scene investigation as it provides visual evidence of the original footprint. A photograph will depict the footprint in relation to the crime scene, allowing investigators to view the complete scene after all of the evidence has been collected. Three-dimensional footwear impressions are most often lifted by casting. Casting, or taking a mold of the impression, will provide a true-to-size physical model of

# Footprint Analysis

the print. When there is worry that the print might be disturbed by the pouring of the casting material, the surface is first prepped. For prints deposited in sand, forensic scientists will spray the print with an aerosol glue or even aerosol hairspray. Water can be drawn away from the surface of a muddy print by using a lab instrument called a pipette, followed by a hot air source, such as a hair dryer. Once the print has been prepped and a frame placed around the print, the casting material is poured into the impression.

Two-dimensional prints are found on surfaces such as glass, wood flooring, cardboard, or fabric and may be lifted using a hydraulic press and gelatin lifters or electrostatic devices. Gelatin lifters are sheets of paper with a strong adhesive on one side that lift the print from most surfaces. More porous surfaces, such as cardboard or fabric, would require the use of a hydraulic press to push down on the gelatin and, thus, enable a print to be lifted in clarity. Electrostatic devices are good for lifting prints from hard to access areas, such as carpeting, wood, and fabric. The electrostatic device uses a high-voltage power unit to charge a metallic film. The film is then placed over the impression where the charge causes the matter forming the impression to cling to the film. Prints can be lifted from almost any surface in this manner, including a human body. Very rarely are criminals careless enough to leave prints made of mud. These would require much effort from the crime scene technicians in lifting the prints.

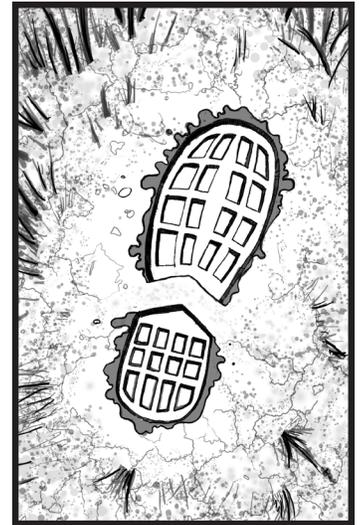
Depending upon the surface and location the print was left, forensic investigators may have a narrow window in which to lift the print. Prints left in blood may last for years, whereas prints left in water may evaporate, and prints made with sand may be brushed away. Realizing this complication, many forensics experts do not take the time required to properly gather prints. Prints from police officers and others on the scene may mix with the prints from the criminal complicating the process. If patience and care are executed, prints that have been

layered with the prints of others at the crime scene may be lifted. Multiple prints may even be lifted at once with a gel lifter. Pages of gel are placed down gently on the surface and then numbered to retain their sequence. Additional pages are then placed down and taped to other pages. Forensics experts are then able to recreate the footsteps at a remote location.

A person interested in a forensics career in footprint analysis should seek a bachelor's degree from an accredited four-year college with a major in criminalistics, chemistry, biology, or physics. To prepare for this, it is recommended that a high school student should pursue classes with an emphasis on sciences and mathematics. Traits of patience and perseverance also prove very beneficial to someone interested in footprints forensics. The American Academy of Forensic Sciences provides a website with a list of colleges and universities providing forensic degree programs. For more information, visit this website: [www.aafs.org](http://www.aafs.org).

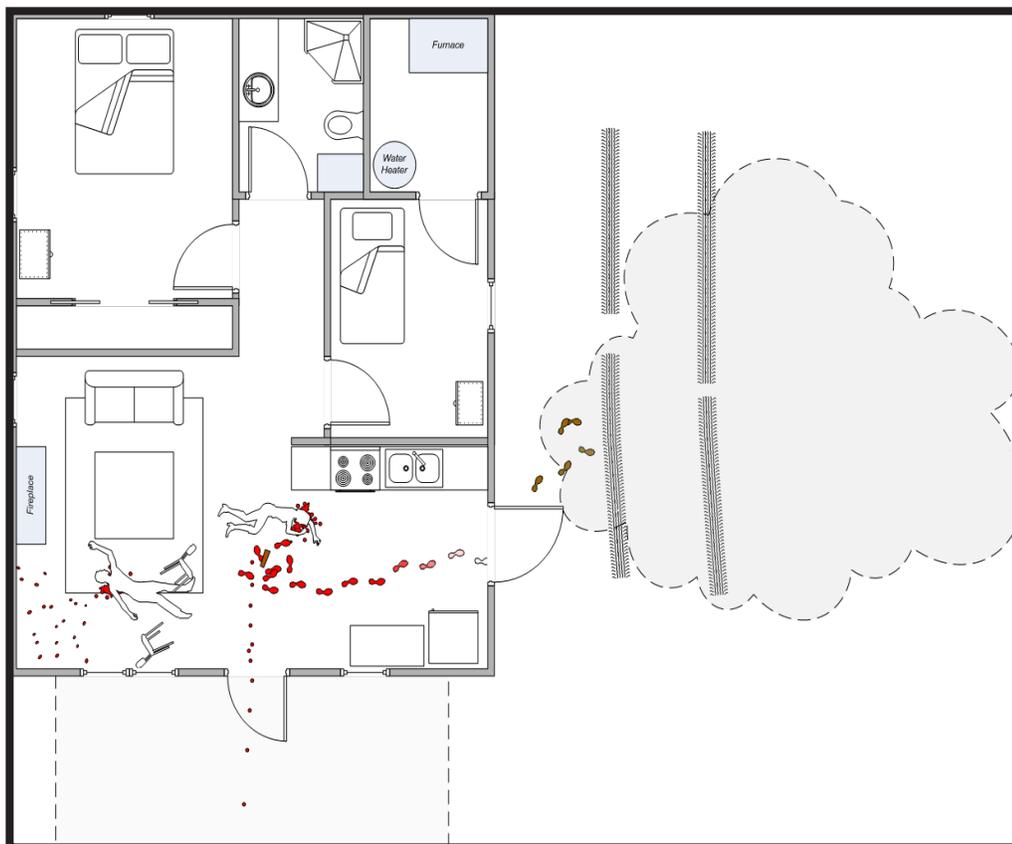
# The Evidence

As investigators collect evidence from in and around the cabin, they find a shoeprint in the mud outside near the tire tracks. All other footprints have washed away in a recent storm, but this print was preserved by the overhanging trees. Since it does not match the shoes of the victims inside the cabin, detectives suspect that this print was left by another person present at the scene of the crime. The print is photographed, and then a cast is made of the shoeprint.



While photographing the blood spatter and droplets that are covering the inside of the cabin, investigators also notice a trail of smudges leading toward the kitchen door. Thinking that the smudges are from the bottom of someone's shoes as they fled the scene, detectives search until they find a partial, smudged shoeprint near the body of the woman. Again, the print does not match the shoes of either victim and could indicate a second suspect if it does not match the print found outside the cabin. The second print is photographed and all evidence is sent to the crime lab for analysis.

Investigators drew a map of the crime scene. The footprints on the diagram are smudges or impressions that investigators thought were possible footprints, but only one inside the cabin was confirmed by experts to be a distinct footprint.



# Pre-Lab Questions

1. What is a two-dimensional footprint?

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2. What is a three-dimensional footprint?

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3. What are individual characteristics?

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4. How do strides indicate whether the walker is a male or female?

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5. What is the correlation between foot length and height?

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6. When investigators are making a casting of a footprint, what do they do to prepare the print?

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7. How long do footprints last at the scene of the crime?

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## Lab 1: Comparing Foot Length to Height

In your lab group, use a ruler or a meter stick to measure your foot length and height in centimeters.

1. Enter the data into your spreadsheet. The spreadsheet will calculate the ratio of height to foot length for each group member.
2. On the second sheet, the spreadsheet will show your group scatter plot for the data. It will also display an equation with the R-value, which is the relationship between the data. A good R-value will be close to 1.0.

## Comparing Foot Length to Height and Stride Length

3. Each group member will walk the premeasured distance while two or three group members count the number of strides taken in the given distance at the individual's typical walking pace.
4. Enter the number of strides for each person into the spreadsheet in column E.
5. Each group member will run the premeasured distance while two or three group members count the number of strides taken in the given distance at the individual's typical running pace.
6. Enter the number of strides for each person into the spreadsheet in column F.

## Analyzing the Data

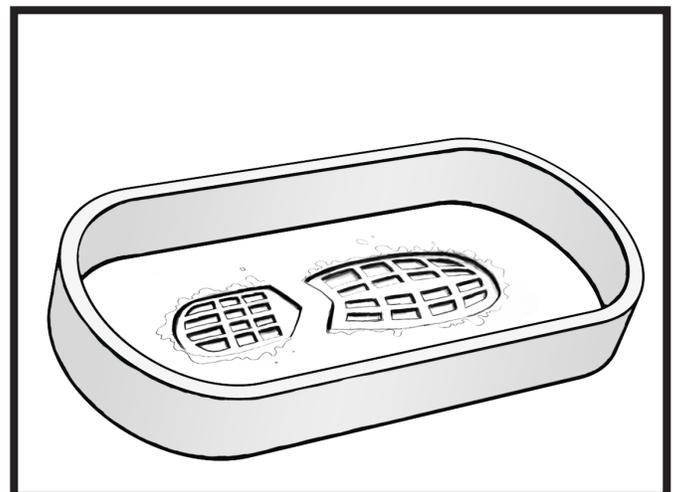
7. The spreadsheet will automatically calculate the length of each person's stride while walking and running by dividing the distance by the number of strides.
8. Study each scatter plot. Determine if foot length can be used to predict height. Test your hypothesis by measuring a person's (from another group) foot length and using your graphs to predict the height. Now measure the height of that person.
9. Examine your data for ratios of stride length to height. Determine if stride length can be used to predict height. Test your hypothesis by getting a person's (from another group) stride length and

using your graphs to predict the height.

10. Look at the class data to compare foot length to height. Examine the other data and compare it to your group data.

## Lab 2: Casting your Shoe Print

1. In your lab group, assign one group member to press their shoe evenly into a tray of damp dirt, or into a flat section of damp dirt outside. Make sure the dirt is only damp—muddy dirt will not keep a good impression! Lift the foot straight up in order to preserve the shoe print.
2. Measure shoeprint (length and width) and record measurements.
3. Add 150 mL (150 g) of water to your bag of dental stone. Mix in the bag by hand kneading, for a minimum of 2 minutes. The consistency of the water and dental stone mixture should be equivalent to thin pancake batter. Refer to directions upon the dental stone bag.
4. If desired, a cardboard strip can be placed around the impression to frame the shoe print and contain the casting material. If using an inexpensive castin material (such as Plaster of Paris), a framing strip would be needed to keep the plaster from running, however, due to the consistency of dental stone, this frame is not necessary for this particular lab.
5. Cut a small corner of the bag and squeeze the dental stone so that it forms an even layer in the



# Lab Procedure

shoe impression. Where possible, do not pour the plaster directly into the impression, as this may damage the impression. Instead, pour the dental stone onto the ground adjacent to the shoe print and allow it to run into the impression. Let the mixture flow slowly into the entire impression.

6. Allow the dental stone to set for at least 30 minutes. After removing, do not clean immediately. Allow casting to set (once removed from dirt) for 12 hours before gently removing dirt with a damp paper towel. NOTE: Casting material mixed to a thinner consistency will require additional time to set before removal.



## Part 2: Examining your Casting

7. Once casting has dried, examine the shoeprint. Look for and record the class characteristics identified on your group casting, such as tread patterns, specific designs or logos, etc. Describe or draw on your data collection sheet. (Class characteristic: A mark that would be common on any shoe of this type.)
8. Identify wear patterns specific to your casting. Describe or draw on your data collection sheet. (Wear patterns: Any erosion of the shoe's sole.) Make a prediction as to whether your group member walks with a pronated, neutral, or supinated foot.
9. Identify individual characteristics on your casting, such as random nicks, cuts, or slices on the shoe's sole. Describe or draw on your data collection sheet. (Individual characteristic: A mark that makes a particular sole unique and thus identifiable.)
10. Trade castings with another group and record class characteristics, wear patterns, and individual characteristics from their casting. Describe or draw on your data collection sheet.

## Lab 3: Examining the Evidence

1. Look at the photograph and crime scene layout provided from the scene of the crime. Note the length of the shoes and any other characteristics you can see from the photograph. Try to find at least 5 class/individual characteristics or wear patterns.
2. Examine the provided evidence casting.
3. Make measurements in regards to tread patterns, distance between tread, etc. Record all measurements for evidence casting and photograph.
4. Identify wear patterns on the evidence casting.
5. Measure the shoe length and make a prediction about the suspect's height.
6. Investigators searched the forensic database, SoleMate, to find all the tread patterns for the athletic shoes ever purchased by most of the men involved in this case. Compare the casting and the photograph to the database of athletic shoes and try to find a match. Unfortunately they were unable to find complete shoe records for Mitch Wilson and Wally Mondelo, however records were obtained for Lyle Mondelo, John Wayne Gretzky, and Larry Gretzky, and these records were then searched against the footwear database.
7. Use the cabin crime scene layout, the photograph, and the casting to recreate the crime scene.

# Footprints Analysis Data Collection

My Group Casting. This shoe print belongs to \_\_\_\_\_.

Class Characteristics	Wear patterns	Individual Characteristics

Other Group Casting. This shoe print belongs to \_\_\_\_\_.

Class Characteristics	Wear patterns	Individual Characteristics

Evidence Photograph and Casting:

Photograph observations and measurements	Casting observations and measurements

# Post-Lab Questions

1. What is the average foot length to height ratio for your group?

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2. What is the average foot length to height ratio for the entire class?

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3. Why are the ratios different from one another?

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4. Can you accurately predict height based on foot or stride length? Why or why not?

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5. What were the wear patterns that you found most often on your examination of the castings?

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6. What did you observe in the photographs? Provide specific details about each shoe print in the photographs.

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7. Were the footprints from the outside and inside made from the same shoe?

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8. What is your conclusion about the evidence shoe print and the suspected type and size of shoe? Are they the same shoe?

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